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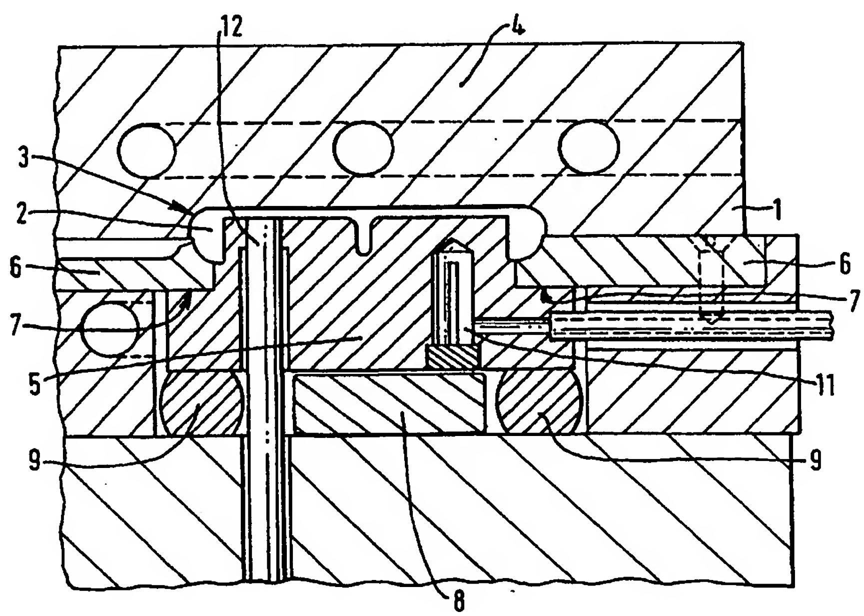
(54) Title: INJECTION MOULDING OF THERMOPLASTIC POLYMERS

(57) Abstract



A method of injection moulding which consists in injecting molten thermoplastic polymer material into a cavity having walls defined by at least two separable mould parts, allowing the thermoplastic polymer material to cool and solidify in the cavity in a cooling phase, separating the mould parts and extracting the solidified material characterized in that one of the mould parts is capable of movement relative to the other mould parts with which it defines the walls of the said cavity and in a direction away from and towards the cavity and in that the injection of molten thermoplastic polymer material is continued until the movable mould part is caused to move to a position away from the cavity by pressure created in the cavity by the injection thereinto of thermoplastic polymer material and wherein as the thermoplastic polymer material in the cavity undergoes shrinkage on cooling the movable mould part is caused to move towards the cavity thus maintaining contact with the injected material in the cavity. The method makes use of a moulding tool comprising at least one cavity (3) defined by at least two separable tool parts (4, 5) characterized in that one of the tool parts (5) is movable relative to the other tool parts with which it defines the cavity (3) and in a direction away from and towards the cavity (3) and in that the moulding tool also comprises resilient urging means (9) which exert pressure on the movable tool part to urge the said part (5) towards the cavity (3), the movable tool part (5) being movable away from the cavity (3), during operation of the moulding tool, by pressure created in the cavity (3) by the continued injection thereinto of molten polymer after the filling of the cavity (3).

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INJECTION MOULDING OF THERMOPLASTIC POLYMERS

The invention relates to a process for the injection moulding of thermoplastic polymers. In such a process, molten polymer material is injected into one or more cavities defined by separable mould parts, allowed to cool and solidify and extracted after the mould parts are separated. Thermoplastic polymers shrink on cooling and this causes sink marks apparent on the surface at regions where the article is thicker than in neighbouring regions.

Sink marks seriously detract from the appearance of moulded thermoplastic articles and efforts have been made to obviate them. One process injects high pressure gas, usually nitrogen, into the partly solidified melt and it is found that the gas forms channels within the melt and permeates principally to relatively thick regions of the article. Here the gas is locked under high pressure and exerts an outward force which inhibits external sinking as the melt cools.

A difficulty with the above described method is that gas flow through the melt is restricted and often cut off at narrow regions of the melt since these usually solidify first. The method is therefore not suitable for some forms of article and in particular may not be suitable for multi-cavity moulds for moulding multiple parts since variation in gas passage profile would cause inequality in part material.

A method designed to overcome the above disadvantages of the prior art processes was proposed in WO93/01039. This reference discloses a method of injection moulding which consists in injecting molten thermoplastic polymer material into a cavity defined by separable mould parts, allowing the material to cool and solidifying in a cooling phase during which a gas is applied under pressure via apertures in the cavity wall to form a pressurised gas layer between the cooling polymer and selected parts of the cavity

wall. Thereafter, the mould parts can be separated and the solidified material extracted.

The method described in WO93/01039 enables the production of precision mouldings which are substantially free of sink marks. This prior art method may be used to produce mouldings which are flat or which contain portions that are substantially flat. When such mouldings are removed from the mould they may appear to be perfect. However, during cooling outside of the mould, minute imperfections which are visible on careful visual examination can be generated at the surfaces of the mouldings. Although we do not wish to be bound by theory we believe such imperfections occur because in some parts of the moulding, the plastics material has not cooled sufficiently such that plastic flow and/or distortion is precluded. This problem is, of course, exacerbated when the moulding is formed of a plastics material having a high shrinkage rate.

The object of the invention is to provide a method of making injection moulded articles in which the risk of post-mould distortion is minimized or removed completely.

Accordingly, the present invention provides a method of injection moulding which consists in injecting molten thermoplastic polymer material into a cavity having walls defined by at least two separable mould parts, allowing the thermoplastic polymer material to cool and solidify in the cavity in a cooling phase, separating the mould parts and extracting the solidified material characterized in that one of the mould parts is capable of movement relative to the other mould parts with which it defines the walls of the said cavity and in a direction away from and towards the cavity, and in that the injection of molten thermoplastic polymer material is continued until the movable mould part is caused to move to a position away from the cavity by pressure created in the cavity by the injection thereinto

of thermoplastic polymer material and wherein as the thermoplastic polymer material in the cavity undergoes shrinkage on cooling the movable mould part is caused to move towards the cavity thus maintaining contact with and pressure on the injected material in the cavity.

The method of the invention makes use of a mould formed by at least two separable mould parts. The mould parts define the walls of the cavity into which the molten thermoplastic polymer material is injected. In conventional methods the mould parts during the moulding operation are rigidly mounted although they are capable of being separated to enable removal of the moulded article. However, according to the present invention one of the mould parts, typically a core member, is capable of movement relative to the other mould parts which, together with the movable mould part, define the walls of the cavity. The extent of the movement of which the movable mould part is capable is between two positions; a forward position in which the movable mould part is normally located, for instance when the molten thermoplastic polymer material is injected into the cavity until the cavity is substantially filled up to which point the pressure exerted on the contents of the cavity by the material being injected thereinto by the injection moulding machine is less than a bias applied to the moveable mould part to maintain it in its forward position and a rearward position in which the movable mould part is located when, during overfilling of the cavity, further molten thermoplastic polymer material is injected into the cavity after the cavity has been substantially filled at which time the pressure exerted on the contents of the cavity by material being injected thereinto by the injection moulding machine is greater than a bias applied to the movable mould part towards its forward position. Typically, the distance of movement between the two positions will be from 2 to 3% of the mean panel thickness of the part to be

moulded. Thus, for a part with a mean panel thickness of 3.0mm, the distance through which the movable mould part is movable, i.e., the distance between its forward and rearward positions, would be approximately 0.06mm and 0.09mm.

The movable mould part is, throughout the moulding operation, urged towards the forward position by resilient urging means, for example, by one or more metal springs, elastomeric spring elements, hydraulic cylinders or a combination of any of these. Thus, in the absence of any pressure, greater than that exerted by the resilient urging means, acting on the movable mould part from the cavity side of the part this part will always be pushed to its forward position.

According to a preferred embodiment in which the movable mould part is a movable core member the moulding cycle is as follows.

1) At the commencement of the cycle the core member is pushed to its forward position by the resilient urging means. In this position the gap between the core member and the mould cavity will be substantially slightly less than the desired panel thickness of the finished cooled moulded part.

2) On filling the mould cavity with the molten thermoplastics material, during which action the pressure in the part-filled cavity is low compared to the external pressure exerted on the core by the resilient urging means, the core does not move from its forward position.

3) As the cavity is overfilled, i.e., as additional molten thermoplastics material in excess of that required to normally fill the cavity is injected into the cavity, the pressure exerted

by the thermoplastics material on the cavity side of the core member is, at this stage, greater than the pressure exerted externally on the core member by the resilient urging means such that the core member is moved to its rearward position against the action of the resilient urging means. The injection of this additional thermoplastics material into the cavity also exerts pressure on the cooling and solidifying thermoplastics polymer material in the mould cavity such that it is urged against the opposing wall of the cavity where sink marks would otherwise be experienced. During this step the cavity is effectively "over-filled" by about 2-3% and is expected to take approximately 3% of the normal cavity filling time, i.e., from 0.1 to 0.3 seconds.

4) The further injection of molten thermoplastics polymer material into the overfilled mould is stopped when the movable core member reaches its rearward position. Typically, the pressure in the thermoplastic polymer material is of the order of 50 to 200 bar depending on the polymer material used and the intended final use of the moulding. Thus, the normal packing or hold phase of conventional injection moulding is not required.

5) As the thermoplastic polymer material in the mould cools it will shrink volumetrically. Shrinkage occurs initially at those parts of the mass of polymer material that are in contact with the cavity walls where cooling takes place and, thus, as the polymer material in the cavity cools it shrinks away from the cavity walls. As the polymer material shrinks away from the wall of the cavity formed by the movable core member the pressure exerted on that member by the polymer material

reduces and the member, under action of the resilient urging means, is biased towards its forward position. By this means, the movable core member is maintained in contact with, and continues to exert pressure on, the cooling polymer material as the latter undergoes shrinkage in the cavity for the whole of the cooling cycle of the mould, i.e., until the mould opens and the part is ejected. By virtue of the pressurised intimate contact of the elements of the mould tool, which are preferably water-cooled, heat is extracted from the moulding such that this moulding will rapidly cool to a low temperature at which plastic flow is prevented. Localised shrinkage marks are, thus, eliminated and 'post mould' shrinkage will be minimised.

According to another aspect of the invention there is provided a moulding tool for use in manufacture of injection moulded articles using a molten thermoplastic polymer material, the tool having at least one cavity defined by at least two separable tool parts, characterised in that one of the tool parts is movable relative to the other tool parts with which it defines the cavity and in a direction away from and towards the cavity and in that the moulding tool also comprises resilient urging means which exert pressure on the movable tool part to urge the said part towards the cavity, the movable tool part being movable away from the cavity, during operation of the moulding tool, under the action of molten thermoplastic polymer material being injected into the cavity after the filling thereof. Preferably, as stated above, the movable tool part is capable of movement between two positions, i.e., a forward position in which the tool part is normally located under the action of pressure exerted thereon by the resilient urging means and a

rearward position in which the tool part is located under the action of pressure, greater than that exerted by the resilient urging means, exerted on the tool part from the cavity side by pressurised molten thermoplastic polymer material. Typically, the distance of movement between the forward position and the rearward position will be 2 to 3% of the mean panel thickness of the part being moulded by the moulding tool.

According to conventional techniques, hollow thick-walled articles are formed by defining a cavity between a central core and an outer mould. In cooling, the polymer shrinks on to the core and loses thermal contact with the outer mould. Consequently, heat must be extracted via the core and because the core size is small and thermal access is restricted the cooling rate is limited. In turn this limits the cycle time of the moulding process. The present invention makes it possible to arrange for the overfilling of a cavity with molten thermoplastic polymer material to urge the polymer melt to contact the outer mould and away from the core, thereby retaining thermal contact between the polymer and the outer mould as the polymer cools. After the cooling polymer melt has been urged towards the outer mould by the pressure created in the melt by the injection moulding machine the core is brought into intimate contact with and to exert pressure on the cooling polymer melt to ensure that heat can be extracted from the polymer not only via the outer mould but also via the core in order to enable rapid cooling of the polymer. The invention is particularly useful to the production of injection moulded articles which are substantially flat or which have flat portions since both sides of the moulding can be cooled rapidly while it is still in the mould. Problems arising from cooling a moulding mainly on one side, as in prior art apparatus, can be overcome.

Thus, according to another aspect of the invention there is provided a moulding tool for the injection moulding of generally flat thermoplastic polymer articles, the tool having a cavity defined between a core and mould characterised in that the core is movable relative to the mould and in a direction away from and towards the cavity and in that the moulding tool also comprises resilient urging means which exert pressure on the core to urge the core towards the cavity wherein the core is movable away from the cavity, during operation

of the moulding tool, under the action of molten thermoplastic polymer material being injected into the cavity after the filling thereof.

The invention will be further described by way of example only with reference to the accompanying Figures in which

FIGURE 1 is a cross-sectional view of part of one embodiment of a moulding tool of the present invention; and FIGURE 2 is an expanded cross-sectional view of part of a second embodiment of a moulding tool of the presentation.

In Figure 1 there is shown a moulding tool 1 which is designed for moulding an article 2 formed in the cavity 3. The tool comprises a cavity plate 4 and a core 5 which are separable and which together define the shape of the cavity. The core is slideable in a core ring 6 such that it is capable of movement between a forward position determined by the edge 7 of the core ring and a rearward position determined by a core stop 8 which is located rearward of the core. The core is biased in its forward position by resilient urging means 9. In a preferred embodiment the resilient urging means comprises one or more elastomeric springs although other types of urging means such as metal springs or hydraulic cylinders can be used instead of elastomeric springs. The resilient urging means should, however, be such that the core is always biased to its forward position.

The core 5 and the core ring 6 are slidable in relation to one another. It is essential, during all phases of the moulding cycle, that the physical gap between the core and the core ring is kept to a minimum to prevent the ingress of molten polymer into the gap. Any such ingress of molten polymer would solidify in the gap and this could prevent the correct operation of the slidable core and/or cause faults on the plastics moulding at this point.

Molten thermoplastic polymer composition is injected into the cavity 3 via a channel 10 by a screw injector (not shown).

As the pressure in the cavity increases as more and more molten thermoplastic polymer material is injected into it the polymer is pushed towards and into contact with the internal surface of the cavity plate. When the pressure of the polymer against the core exceeds the pressure exerted on the core by the

resilient urging means 9 the core is caused to move against the bias created by the urging means 9 in a rearward direction until it contacts the core stop 8. At this point, the core is located at its rearward position and the cavity is overfilled by 2 to 3%.

After the polymer has been forced into contact with the cavity plate and the core has reached its rearward position the injection of molten polymer is stopped. As the polymer in the cavity cools it tends to shrink away from the core. However, since the core is biased to its forward position by the pressure exerted on the core by the resilient urging means the core is caused to move towards its forward position as the polymer recedes from the core due to shrinkage. The core is thus maintained in contact with the gradually shrinking polymer and in this way it returns gradually towards its forward position.

The effect of this is to allow the core to conduct heat away from the polymer in the cavity so that the polymer is cooled by the core as well as by the cavity plate thus ensuring rapid and consistent cooling of the injection moulding. Accelerated cooling of the core may be achieved by means of cooling water being supplied to the core by a pipe system 11. The moulded article 2, when cooled sufficiently can be ejected from the mould by an ejector pin 12.

In Figure 1 the slidable fit between core 5 and the core ring 6 is shown to be of a parallel form, i.e., the surface of the core ring against which the core is slidable and the opposing surface of the core are vertical which is the case when the internal diameter of the core ring at its surface against which the core is slidable, is constant. According to a preferred embodiment of the invention the fit between the core 5 and the core ring 6 is of a tapered form. Such an embodiment is illustrated in Figure 2 which shows an expanded view of the interface between the core and the core ring.

In Figure 2, the fit between the core 5 and the core ring 6 is of a tapered form. By this it is meant that the surface of the core ring against which the core is slidable tapers inwardly towards the bottom of the core ring and the opposing surface of the core is correspondingly tapered outwards the bottom of the core. A tapering fit is arranged when the internal diameter of the core ring. at its

surface against which the core is slidable, gradually increases in a direction away from the cavity and the width of the core correspondingly increases gradually.

The angle of taper will typically be in the range of from 2° to 4° depending on the movement required.

With the core in its fully forward position it is arranged that there is no gap between the core and the core ring to ensure that the core can be accurately located and, also, to prevent the ingress of molten polymer between the core and core ring during the initial filling of the cavity. As soon as the molten polymer touches the tooling it will cool and form a skin of solidified thermoplastic. When the molten polymer fully fills the cavity and the injection system of the moulding machine pressurizes the molten portion of the moulding in the cavity, this pressure will force the core 5 and the core back plate 5A rearwards to the core stop 8. This causes core 5 to move relative to the core ring 6 resulting in the creation of a small gap between them. This gap will typically be of the order of 0.003mm in the case where the taper angle is about 4°. A tooling gap of such a size does not allow the ingress of molten polymer during normal moulding operations. The practical advantages of using a tapered fit between the core 5 and the core ring 6 include:

(1) the core 5, when at its fully forward position, is accurately located by the taper in the core ring and will readily return to this precise position on completion of each moulding cycle;

(2) the gap between the core and the core ring, when the core is at its fully forward position, is zero thus preventing any ingress of the molten polymer during the injection stage when the polymer is in its most fluid condition; and

(3) the gap which results between the core and the core ring when the core is in its most rearward position and when the pressure applied to plastic part is at its highest during the moulding cycle as well below normal engineering "fits" designed to prevent the ingress of molten polymer in injection moulding tools.

Some of the other benefits of the invention may be summarised as follows:-

Product Quality

For flat thermoplastic mouldings, this process offers an economic route to obtaining effectively precision mouldings which are evenly stressed with consequential low warpage. This is essential for high strength parts. The mouldings are 'sink free'.

Product Innovation

With innovative tooling design, parts can be manufactured with relatively simple tooling, that would be only possible, if at all, by expensive tooling running on slow cycles. Freedom in part design is allowed since requirements to hide sink marks are relaxed.

Cycle Benefits

Although the time taken to overfill the mould is significantly less than the normal packing or hold phase the major cycle benefit achieved by the present invention is derived from cooling the injected polymer material on both sides compared to just one side as in conventional techniques.

Machine Size Benefits

In many moulding systems, the size (and therefore cost) of the moulding machine is determined by the 'packing pressure' necessary to minimise 'sinks' on the part. This packing pressure tends to be relatively high, because as the part cools, it becomes progressively more difficult to inject molten material into features far away from the 'gate'.

Using the invention, however, the melt remains relatively hot throughout the filling and overfilling phases and therefore the pressure can be a minimum. Thus, it allows an increase in the size of part which can be moulded on a given sized machine with associated reduction in costs to the customer.

Cheaper Tooling

Because internal moulding stresses are reduced and there is less likelihood of the mould to flash it is possible to use less expensive tooling.

Smaller Gate Marks

Where the moulding "gate mark" is in a highly visible position, the size of this mark becomes a critical quality parameter. The gate diameter is substantially controlled by the length of the "packing phase" required, so that the gate does not freeze. However, when using this process this consideration no longer applies and the gate diameter may be the minimum necessary to fill the part.

Shrinkage Prediction

Using conventional moulding techniques it has been found to be extremely difficult to predict the precise shrinkage value for each discrete element of a part. Since this shrinkage value is influenced by the following plastic conditions during moulding:-

(a) plastic temperature profile;

(b) plastic stress profile; and

(c) whether the element is free to shrink, or is restrained by the mould core or cavity.

Since using this process will reduce the variation of all of these parameters it is expected that this shrinkage value will show significantly less variation, and will therefore be easier to predict.

CLAIMS

1. A method of injection moulding which consists in injecting molten thermoplastic polymer material into a cavity having walls defined by at least two separable mould parts, allowing the thermoplastic polymer material to cool and solidify in the cavity in a cooling phase, separating the mould parts and extracting the solidified material characterized in that one of the mould parts is capable of movement relative to the other mould parts with which it defines the walls of the said cavity and in a direction away from and towards the cavity and in that the injection of molten thermoplastic polymer material is continued until the movable mould part is caused to move to a position away from the cavity by pressure created in the cavity by the injection thereinto of thermoplastic polymer material and wherein as the thermoplastic polymer material in the cavity undergoes shrinkage on cooling the movable mould part is caused to move towards the cavity thus maintaining contact with the injected material in the cavity.

2. A method according to claim 1, wherein the movable mould part is biased towards the cavity by resilient urging means.

3. A method according to claim 2, wherein the resilient urging means are selected from elastomeric springs, metal springs, hydraulic cylinders and a combination of two or more of these.

4. A method as claimed in any one of claims 1 to 3, wherein the mould is a multi-cavity mould.

5. A moulding tool for use in the manufacture of injection moulded articles using a molten thermoplastic polymer material the tool having at least one cavity (3) defined by at least two separable tool parts (4, 5) characterised in that one of the tool parts (5) is movable relative to the other tool parts with which it defines the cavity (3) and in a direction away from and towards the cavity (3)

and in that the moulding tool also comprises resilient urging means (9) which exert pressure on the movable tool part to urge the said part (5) towards the cavity (3), the movable tool part (5) being movable away from the cavity (3), during operation of the moulding tool, by pressure created in the cavity (3) by the continued injection thereinto of molten polymer after the filling of the cavity (3).

6. A moulding tool according to claim 5, wherein the movable tool part is biased towards the cavity by resilient urging means (9).

7. A moulding tool according to claim 6, wherein the resilient urging means (9) are selected from elastomeric springs, metal springs, hydraulic cylinders and a combination of two or more of these.

8. A moulding tool according to any one of claims 5 to 7, wherein the movable tool part (5) is capable of movement between a forward position and a rearward position, the tool part (5) being located, during operation of the moulding tool, in the forward position except when pushed to its rearward position by pressure created in the cavity by the continued injection thereto of molten polymer after the filling of the cavity.

9. A moulding tool for the injection moulding of generally flat thermoplastic polymer articles, the tool having a cavity (3) defined between a core (5) and mould (4), characterised in that the core (5) is movable relative to the mould (4) and in a direction away from and towards the cavity (3) and in that the moulding tool also comprises resilient urging means (9) which exert pressure on the core (5) to urge the core (5) towards the cavity (3) wherein the core (5) is movable away from the cavity (3), during operation of the moulding tool, under the action of molten thermoplastic polymer material being injected into the cavity after the filling thereof.

10. A moulding tool according to claim 9, wherein the core (5) is biased towards the mould (4) by resilient urging means (9).

11. A moulding tool according to claim 10, wherein the resilient urging means (9) are selected from elastomeric springs, metal springs, hydraulic cylinders and a combination of two or more of these.

12. A moulding tool according to any one of claims 9 to 11, wherein the core (5) is capable of movement between a forward position and a rearward position, the core (5) being located, during operation of the moulding tool, in the forward position except when pushed to its rearward position by pressure created in the cavity (3) by the continued injection thereinto of molten polymer after the filling of the cavity.

13. A moulding tool according to any one of claims 5 to 12, wherein the core (5) is slidable in a core ring (6) and wherein the surface of the core ring (6) against which the core (5) is slidable and the opposing surface of the core (5) are vertical.

14. A moulding tool according to any one of claims 5 to 12, wherein the core (5) is slidable in a core ring (6) in a tapering fit.

FIG. 1.

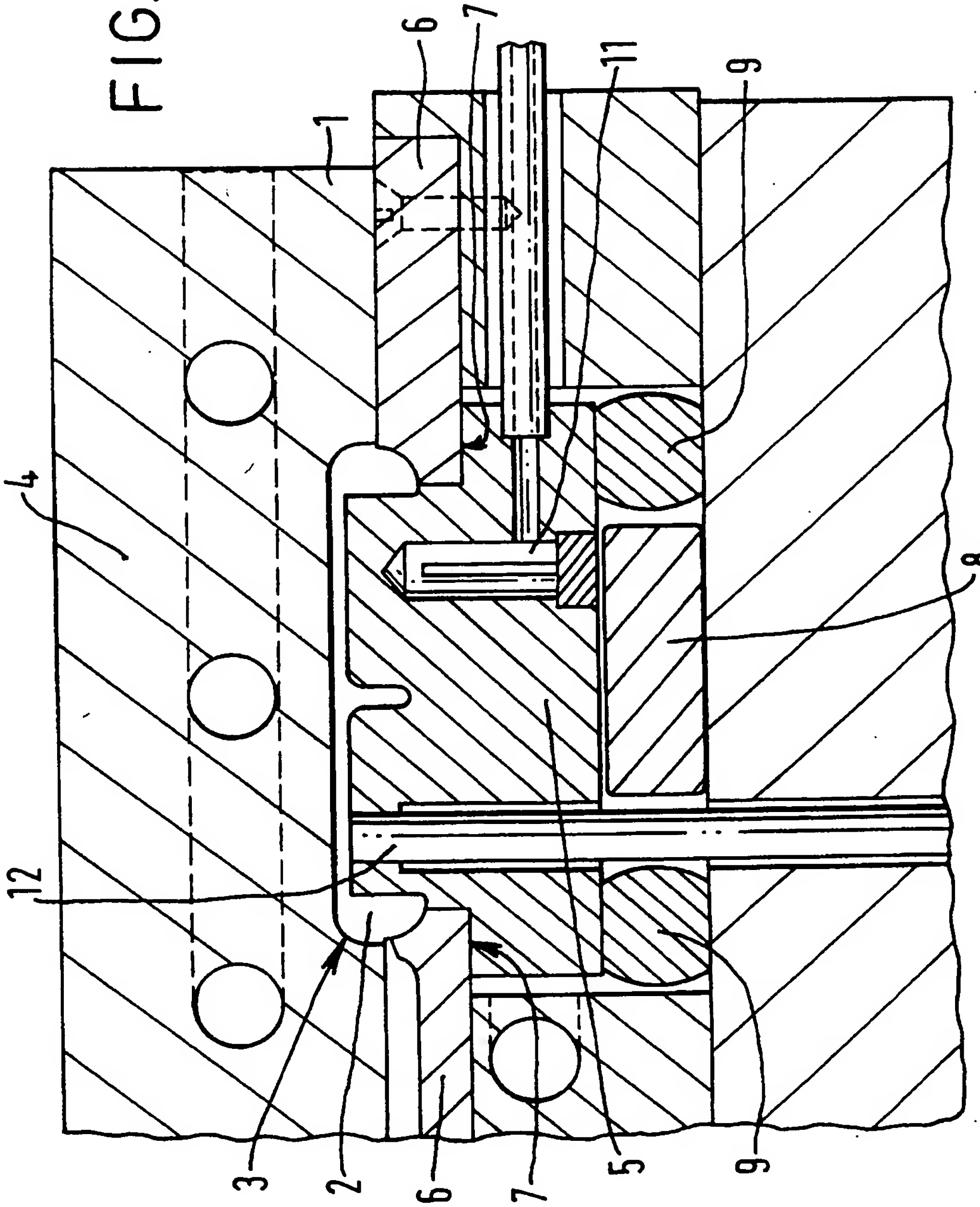
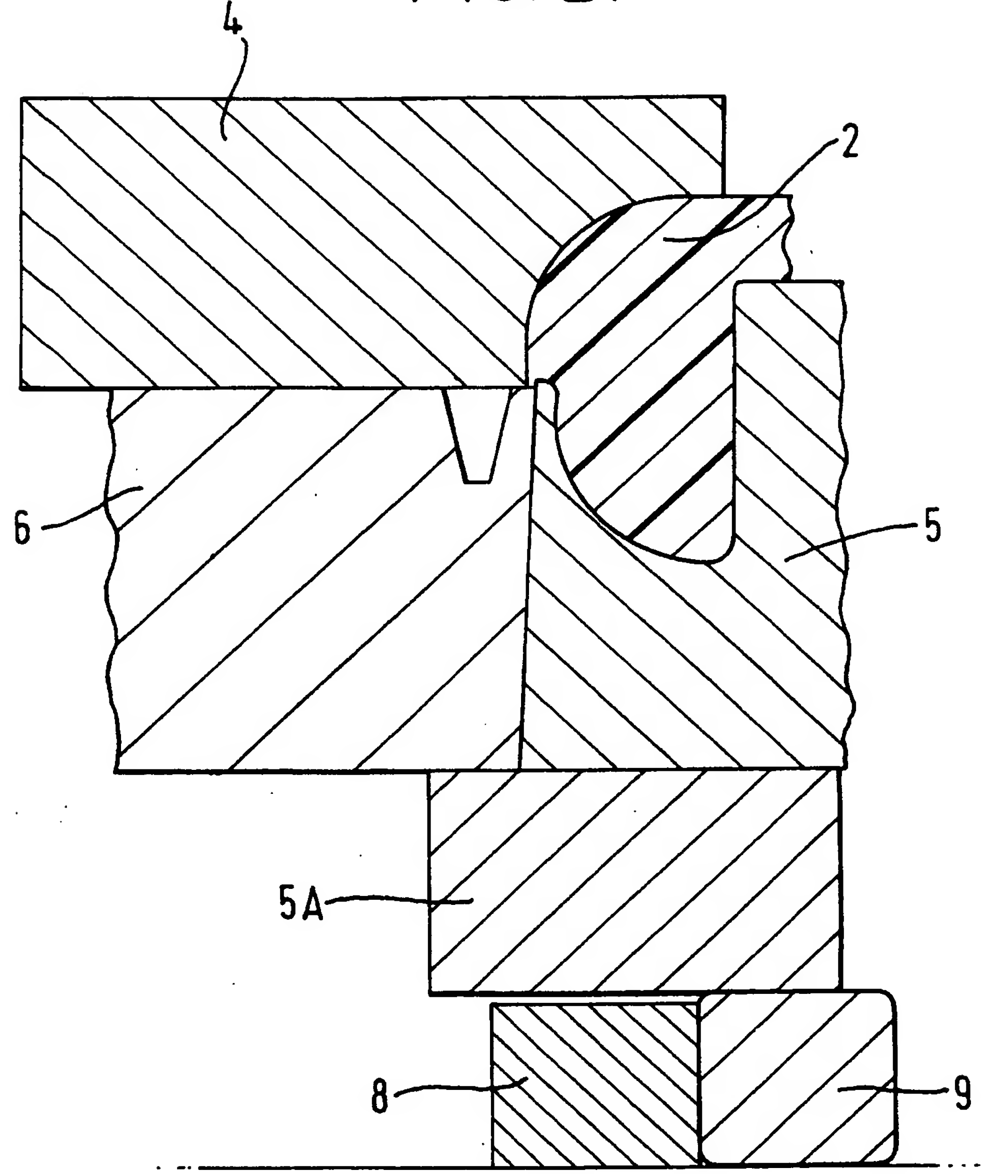


FIG. 2.



INTERNATIONAL SEARCH REPORT

I. .national Application No
PCT/GB 98/01590

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B29C45/56

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 050 928 A (OMNITECH INC) 14 January 1981 see the whole document ---	1-13
X	DE 44 42 536 A (BAYER AG; MASCHINENFABRIK HENNECKE GMBH) 14 September 1995 see the whole document ---	1-12
X	US 2 443 826 A (J. JOHNSON) 22 June 1948 see the whole document ---	1-13
X	WO 90 14207 A (MAUS STEVEN M; GALIC GEORGE J) 29 November 1990 see the whole document ---	1-3,5-13
X	US 2 781 547 A (S.K. MOXNESS) 19 February 1957 see the whole document ---	1-3,5-13

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 September 1998	14/09/1998

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International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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